IJEAST

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY

VOLUME : 4 ISSUE : 07 Print / Issue Publication Date: 07-Jan-2020

ISSN : 2455-2143

DOI : 10.33564/IJEAST.2019.v04i07.023

Indexed In

Google Scholar · OPEN ACCESS · doi · Crossref

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International Journal of Engineering Applied Sciences and Technology, 2019
Vol. 4, Issue 7, ISSN No. 2455-2143, Pages 149-154
Published Online November 2019 in IJEAST (http://www.ijeast.com)

MECHANICAL CHARACTERIZATION OF HYBRID LAMINATES COMPOSITES ON EPOXY RESIN WITH NATURAL JUTE FIBER AND S-GLASS FIBERS

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Abstract: The natural jute fiber existed on the earth surface at free of cost. These jute fibers over the hundreds of year have been used in applications of making beds, ropes, and artificial bags. For current demands, the hybrid materials are essential to multiple processing properties for structural aspects and product design. In this paper, the hand layup techniques were used by LY556 epoxy resin and LY591 hardener to develop the S-glass fiber/epoxy resin (50%) varying 15%, 20% and 25% of jute fiber. The experimental investigation of hybrid polymer composites were determined as per ASTM standards. This result indicates that composition of 25% of jute fiber has better strength compared to S-glass fiber/epoxy resin as base matrix phase.

Keywords: *Epoxy resin, jute fiber; hand layup; hybrid polymer composites; S-glass fiber:*

I. INTRODUCTION

The new class of engineering materials was emerged to match the gap between industrial and aerospace field of scope at various processing of material design. In this case, the natural fiber plays vital role in the polymer composites. The reason behind that they are renewable, biodegradable, cheaply available, and completely or partially recyclable. The promising natural jute fibers are freely available in abundant at low cost. These natural fiber acts as reinforced phase in combination of epoxy/resin type of matrix phase and its relatively inexpensive. The hybrid composites are extraordinary materials to robust the excellent properties in glass fiber reinforced polymer composites (GFRPC).Its established good strength, toughness, and behaves as fine grain size of fibers. The superior mechanical characteristic had found on oil palm empty fruit bench (OPEB) with hybrid glass fibers and observed the effects of elongation property. These results indicate light weight composites and cost effective are established with phenol-formaldehyde resin [1]. They identified failure behavior on long and short glass fibers with reinforced of poly-polypropylene [2]. For recent years, it has been reported for finding applications of natural fibers as cost effective for traditionally usage of making carpets, ropes, and making artificial blankets[3]-[4]. The determined rheological and mechanical properties for propylene-ethylidenenorbornene-elastomeric, and a non-reactive surfactant were investigated [5]. The different amount of short and glass fiber reinforcement with matrix phase such as polyethylene-terpthalate, nylon6, and poly-proethylene. They studied the Izod impact energy absorbed over the range of temperature 22-23^{0}c [6]. They explained the effects of tensile properties behavior with injection molded long fiber thermoplastic composites [7]. The current methodology to study the 3-D images enabled porosity of laminates thickness, fraction ovoid content, the morphology, and location of fibers. For developed stacking alignments of fiber glasses with carbon-reinforced hybrid composites. They studied and explained the impregnation quality with void formation [8]. In connection of compressive binding and tensile strength effects on bi-directional nylon and matrix phase of steel effects in binder of polyester acts as reinforcement. They studied and reported as specimen’s having higher percentage of load sustainability on steel with strength of tensile is rapidly increases at orientation of specimens 0/90^0 [9]. The higher renewable contents and superior performance with composite were successfully produced from fibers and resin [10].

II. METHODOLOGY

i) Materials used

The base matrix phase of epoxy resin as LY556 and HY591 hardener was purchased from Chemist Engineers Limited, Bangalore, India. For reinforced phase as bidirectional jute fiber of thickness 0.4mm was used and S-glass fiber in woven as 280gsm supplied by Suntech Fiber Private Limited. The chemical composition and physical properties of epoxy/S-glass fiber/jute fiber as shown in below [11].

Table.1 The chemical composition of S-glass fiber

Elements	SiO_2	Al_2O_3	MgO
Percentage (%)	65	25	10

Table.2 The natural jute fiber composition

Elements:	Flat-cellulose	Hemicelluloses	Lignin	Source
Percentage (%)	51-84	12-20	5-13	5

Table.3 The chemical composition of epoxy resin at 23^0c

Elements	Resin	Hardener	Aluminum	HNT
Percentage (%)	63	27	10	….

Table.4 Thermo-physical parameters of jute fiber

Physical properties	Specifications
Moisture content regain (%)	13.75
Density of jute fiber(kg/m^3)	1.35
Elongation at break (%)	1.8
Young modulus(GPa)	32
Tensile strength(MPa)	705-825

Table.5 Thermo-physical parameters of S-glass fiber

Physical properties	Specifications
Thermal expansion(μm/m-^{0}c)	5.26
Density of S-glass fiber(kg/m^3)	2.49
Young modulus(GPa)	89
Elongation at break (%)	5.4
Tensile strength(MPa)	4750

ii) The process of hand lay-up techniques.

For developing polymer laminates composites and required space is minimal with processing steps are quite easier. In the first stage, a spread out the gel by spraying on the mould surface for avoiding sticking on the epoxy surface. A good surface finishes at laminate composites, the top portion of thin sheets and bottom portion of mould plate to be properly assigned. For jute fibers are formed by woven mat jute fabrics as required thickness size of 3mm as S-glass fibers were cutes for size of the mould plate and thereafter sheets of Perspex are provided. The mixed form of liquid epoxy resin in proper alignment to the perfect composition with prescribed hardener and then pouring then pouring into the mould surface. The help of brush spread uniformly epoxy resin on surface and second layer to be applying mild pressure on layer of epoxy surface to remove the excess of epoxy on the layer of surface. Each layers of epoxy and mat will be continued until obtain required layers were stacked. The placing of sheets of plastic and released gel to spread out for top portion of mould plate surface is kept on the layers of stitched with applied pressure. Finally, at room temperature some specific temperature is to be maintained (60^0-80^0c) for curing process. However, a part of developed laminates composites is taken out for further processing of normal curing at time duration of 24-48hrs [12].

Fig. 1: (a) The first layer glass fiber mat with jute fiber by hand lay-up method;

Fig. 1: (b) For second layer enclosed with glass fiber

Fig. 2: (a) The sample of Epoxy/S-glass (50%)/jute fiber (10%)

Fig. 2: (b) For jute fiber (25%)

Table.6 The polymer laminates stacking sequence

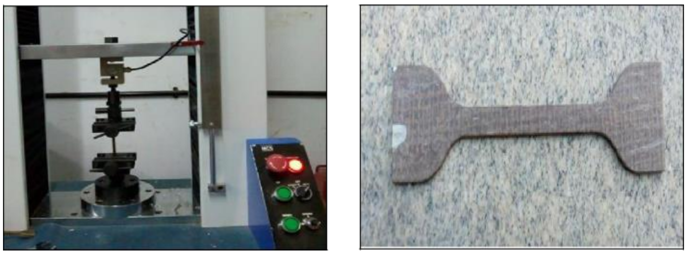
Composites	Composition
GE ----➔	Glass fiber + Epoxy resin
GEJF1 ----➔	S-glass fiber (35%) +Epoxy resin (50%) +Jute fiber (15%)
GEJF2----➔	S-glass fiber (30%) +Epoxy resin (50%) +Jute fiber (20%)
GEJF3----➔	S-glass fiber (25%) +Epoxy resin (50%) +Jute fiber (25%)

iii) The specimen preparation

The laminates of hybrid composites stacking sequencing are established by varying 15%, 20%, and 25% jute fiber with orientation of $0/90^0$. In these composites, the epoxy resin keeping balancing with S-glass fiber to study the mechanical characterization and preparation of specimen's samples was followed by American Standards for Testing Standards (ASTM).

1. Tensile testing

The ASTM-D3039 standard method was followed for determining the tensile properties of plastics and testing accuracy between ±1%. For specimens samples size (216x19x3mm3) and maximum load withstands capacity of 100kN (see fig.3a). During the testing different composition of laminates composites and its observed that specimens holding the grip of load corresponding to deflections were noted. The ultimate load capacity, tensile strength, stress, strain, and young modulus were recorded [13].



(A) (B)

Fig.3: (a) The Universal testing machine of capacity of load 100kN; (b) Tested tensile sample as per ASTM-D638

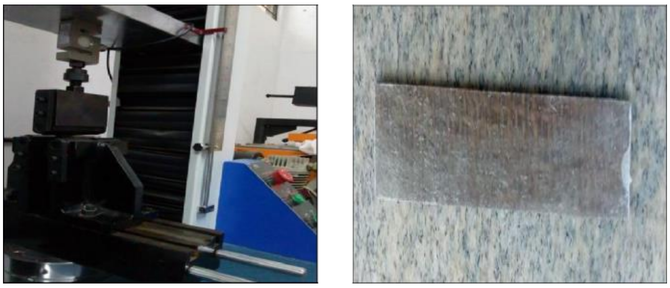
2. Impact testing

The Izod impact testing has done as per ASTM-D256 standards with specimen sample size ($65x12.5x3mm^3$) has been followed with relative humidity (68%) and lab temperature was found 29^0c. It's observed that hybrid laminates composites were significantly increased the impact strength and toughness of the materials [14].

Fig.4: (a) The Izod impact apparatus of capacity of 800N; (b) Tested impact strength sample as per ASTM-D256

3. Flexural testing

The three points flexural tested as per ASTM-D790 standards with specimen sample size ($80x8x3mm^3$). The fracture and bending point of samples after the load applied at the middle of specimens was carried out on UTM. The graph is generated due to applied breaking load versus length of sample [15].



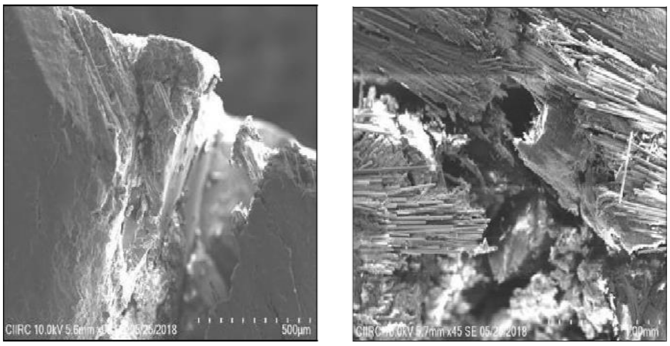
(a) (b)

Fig.5: (a)The Universal flexural testing apparatus of capacity of 800N; (b) Tested sample of flexural strength as per ASTM-D790

III. RESULTS AND DISCUSSION

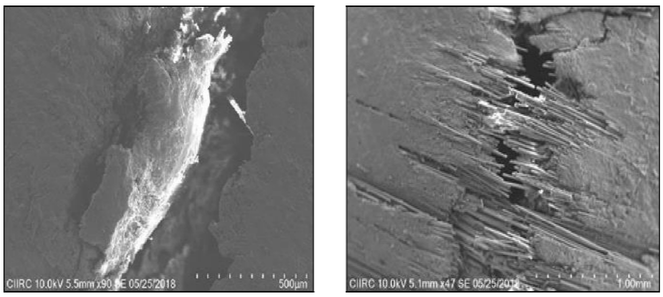
1. Microstructure characterization

The specimen's samples were analyzed by the scanning electron microscope [16]. These samples images of epoxy resin/S-glass fiber/jute fiber hybrid laminates composites is observed with reduction in strength and better reasons for failure. The agglomeration of jute fiber and phase of the matrix was visible at 500μm magnification of SEM mages are provided (see fig.6a). In the 1.00μm magnification of jute fiber shows some air gaps and its reduces the impact strength during the testing of composites (see fig.6b).



(a) (b)

Fig.6 (a) 500μm magnification of SEM images of GEJF1; (b) 1.00μm magnification of SEM images of GEJF1



(a) (b)

Fig.6: (a) 500μm magnification of SEM images of GEJF3; (b) 1.00μm magnification of SEM images of GEJF3.

The considerable amount of composites strength gets reduced due to poor-fiber-matrix adhesion and visible of fracture side of tension due to pull out of extensive fibers (see

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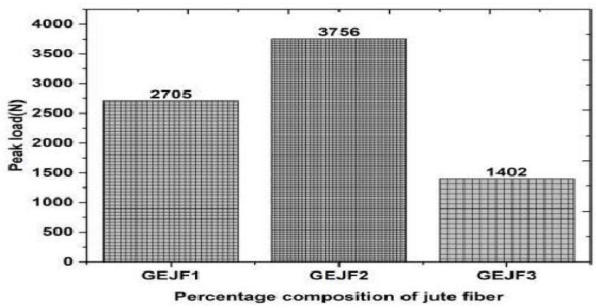
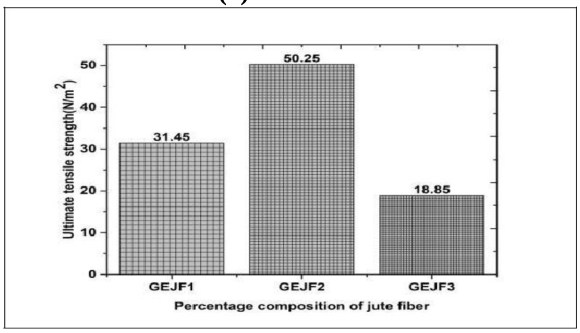
fig.7a). The factors which influences such as adhesion of matrix phase, presence of air void, dispersion of fiber, agglomerations of fibers, and fibers orientation. These factors reduce the strength of fiber reinforced composites. The strength of the composites also decreases due to the distribution of non-uniform alignments of jute fibers in reinforced phase (see fig 7b).

2 Tensile properties

The composition of epoxy resin/S-glass fiber/jute fiber of hybrid laminated composites is designated as GEFJ1.GEFJ2 and GEFJ3. The GEFJ2 of jute fiber composition of composites samples are with stands peak load capacity (3756N) and rapidly reduces with GEFJ1 is reached at 2705N and lowest load carrying at 1402N (see fig 8a). The universal testing machine with capacity of load 100Kn was used to estimate the ultimate tensile strength of the composites. It notice that tensile strength of GEJF2 (50N/mm^2) were better yield in the results compared to GEFJ1 (36.56N/mm^2) and GEFJ3 (18.65N/mm^2) (see fig 8b).



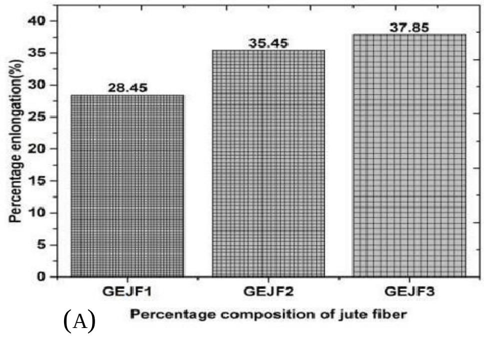
(a)



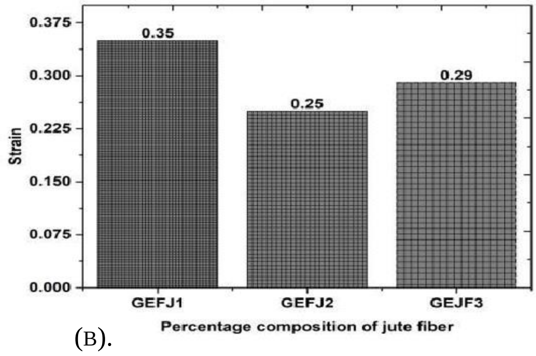
(b)

Fig 8: (a).The variation of peak load versus percentage composition of jute fiber ;(b) for ultimate tensile strength

Tested specimens samples of tensile materials shows maximum elongations at 37.85% of GEFJ3 and minimum elongations were reached at 28.45% of GEFJ1 (see fig 9a). The behavior of strain due to tensile strength, the higher strain obtained at 0.37 of GEFJ1 and slightly reduced at 0.28 of GEFJ2 (see fig 9b). The displacement yield versus load applied on tensile specimen samples lies between 2.75mm (1405N) and 4.00mm (3756N) of composites respectively.



(A)



(B).

Fig.9: (a).The percentage elongation versus composition of jute fiber; (b) The variation of strain for tensile specimens

The above results of tensile specimen's samples of tensile properties of hybrid laminates composites were determined by the following relations [17]-[18].

The ultimate tensile strength is determined by the relation

$$(\sigma_t) = \frac{P}{bxh} \quad (1)$$

The young modulus of a specimen samples are estimated by the equation

$$(E) = \frac{\sigma_t}{\varepsilon} \quad (2)$$

The tensile strain can be calculated by the relation

$$(\varepsilon) = \frac{\Delta L}{L} \quad (3)$$

3. Flexural properties

The specimen samples were carried out to on UTM to three point bending test with maximum load capacity of 100kN. The flexural strength can be found at 1146N/mm^2 (GEJF1) and higher strength is achieved at1175N/mm^2 (GEJF2) with lower strength can be reached at 880N/mm^2 (GEJF3) (see fig 10a).

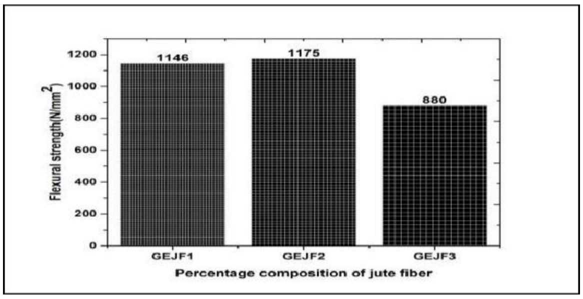


Fig.10: (a).The variation of flexural strength versus composition of jute fiber.

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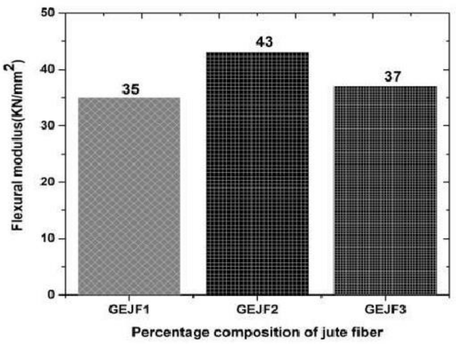


FIG.10: (B) FOR FLEXURAL MODULUS OF A SPECIMENS

A tested specimens sample withstands maximum displacement versus load applied lies between 12.75mm (720N) and 4.75mm (375N) respectively. From these observations, a higher flexural modulus is obtained at 43kN/mm^2 (GEJF2) and a lower modulus was achieved at 35kN/mm^2 (GEJF1) (see fig 10b). A measured ductility of samples and modulus of flexural indicates stiffness and toughness. Its leads to the deformation at some extent when applied to the bending stress.

The strength of the flexural test is calculated by the equation [19]-[20].

$$(\sigma_f) = \frac{3PL}{2bh^2} \qquad (4)$$

The flexural modulus can be estimated by the relation

$$(E_f) = \frac{t^3 m}{4bh^3} \qquad (5)$$

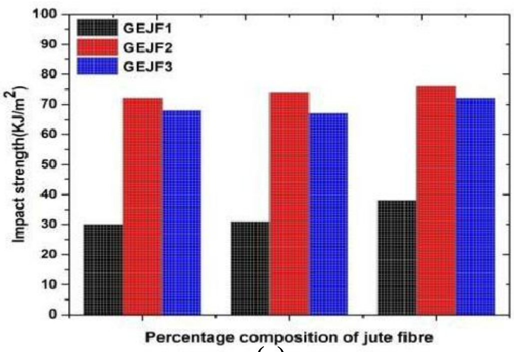
The flexural strain is determined by the equation

$$(\varepsilon_f) = \frac{68h}{B^2} \qquad (6)$$

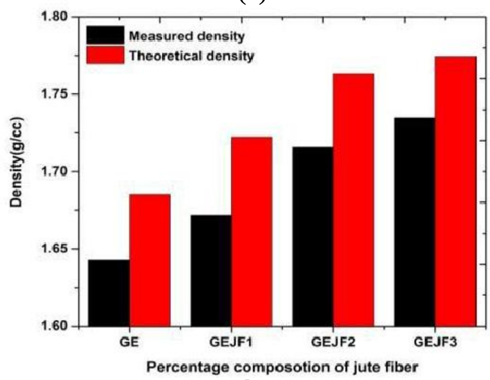
4 Impact properties

For determining the Izod pendulum impact strength was followed by the ASTM standards. In order to analyze the better results, the lab temperature maintained at 29^0 with relative humidity 68%.The hybrid laminates composites are also incorporated with fiber orientation at ± 45^0 angles in the core to maximize the impact strength in testing. It has found that higher impact energy release at 74kJ/m^2 (GEJF2) and lowest impact energy recorded at 30kJ/m^2 (GEJF1). The testing results of fracture work are higher due to contain of higher cellulose and lower micro fiber angles. (See fig 11a). The measured and theoretical densities are calculated on the bases of rule of mixture properties of hybrid laminates composites to identify the percentage of void fraction. Due to reduction of fatigue resistance, the greater susceptibility to water penetration and weathering .At work place, the significantly affects the mechanical properties and the performance of the composites. It was noticed that natural jute fibers have higher voids contents than that of the other type fibers. (See fig 11b).

Absorbed energy measured= (After the specimen at break load applied-Before the specimen at hammer)



(a)



(b)

Fig.11: (a). The variation of impact strength versus composition of jute fiber; (b) The variation of densities of laminates composites

IV. CONCLUSION

The experimental investigation on natural fibers incorporated with epoxy resin and S-glass fiber of composites is studied and following points were concluded.

1. The epoxy resin based S-glass fiber with natural jute fibers were successfully analyzed as per ASTM standards.
2. It has found that ultimate tensile strength of GEJF2 and GEJF1 of composites are 50N/mm^2 and 18.65N/mm^2. Due o addition of 25% jute fiber on base matrix phase of epoxy resin are encountered the belter yield in results compared to GEJF1.
3. The young modulus of tensile specimens samples of GEJF2 and GEJF3 of composites are 178.57MPa and 66.65MPa. The percentage of elongation of tested materials was performed between 38.65% and 28.75% with leads to the reason of uniform transfer of stress across the composites laminates.
4. The flexural strength of composites was established to be 1175N/mm^2 and 880N/mm^2 with increases in the results of samples of GEJF2. The recorded flexural modulus lies between 43GPa and 35GPa with maximum displacement of samples is 12.75mm and it indicates that better stiffness and greater extent of deformation of materials.
5. The higher impact energy released by the composites were 74kJ/m^2 during the samples of GEJF2 compared to other laminates due to content of low fibril angle of fibers and its leads to higher work area of fracture.

6. However, the researches of this present study on hybrid composites compress the behavior of mechanical properties and its was noticed that better strength, toughness and toughness with combination of two different plane of fibers are play's vital role in the field of automotive and some parts of aerospace applications.

ACKNOWLEDGMENTS

The authors are grateful to Dr. Peter Thomas, Joint Director, and Central Power research Institute, Karnataka State, India. For his support to studied the experimental investigation.

	Nomenclature	**Greek symbols**
P	Load applied (KN)	σ =Ultimate strength of samples (KN/mm^2)
b	Sample of initial width(mm)	ε =Strain of samples (mm)
h	Thickness of sample(mm)	
E	Modulus of elastic (MPa)	
L	Original length of samples (mm)	
ΔL	Change in length of samples (mm)	
M	Slope of load deflection of curve (N)	
B	Distance between supports (mm)	
S	Spain to displacement ratio	

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